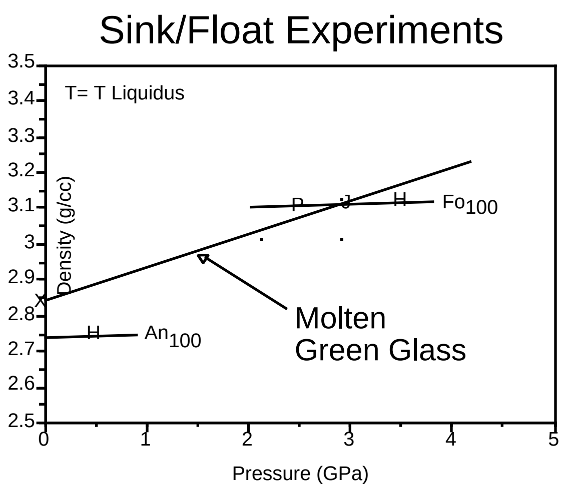
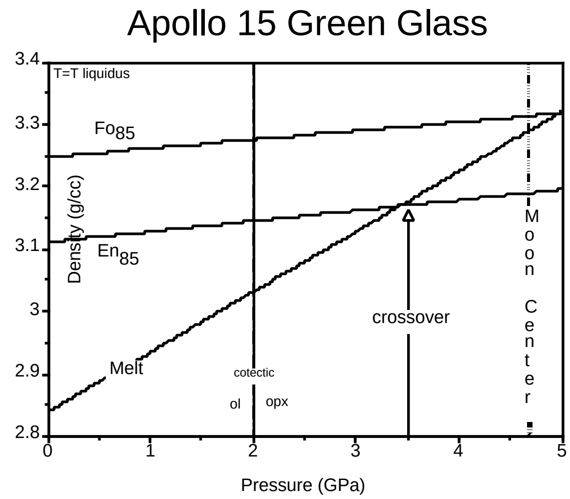
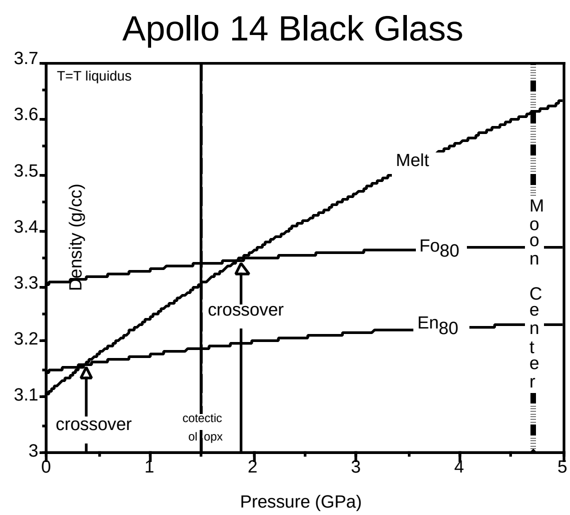
DENSITY CROSSOVERS IN LUNAR PICRITES. C. B. Agee[1], J. R. Smith[1] and P. Courtial[2], [1]Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, U.S.A., agee@eps.harvard.edu, [2]Bayerisches Geoinstitut, University of Bayreuth, D-95440 Bayreuth, Germany, phillipe.courtial@uni-bayreuth.de.

Summary. In this study we report experimental confirmation of crystal/liquid density crossovers in two "pristine" lunar picritic glasses. Pristine lunar glasses are logical candidates for study of mare basalt petrogenesis because they seem to represent the most primitive mare basalt compositions available. The information gained from these experiments can also be used to elucidate the effect of pressure, temperature, and composition on silicate melt bulk modulus (K). Our evaluation of data on high-Ti lunar picrite (Apollo 14 black glass) suggests that dK/dT and dK/dP (K') change significantly with temperature and pressure. Our analysis also indicates that K' may vary with melt composition.

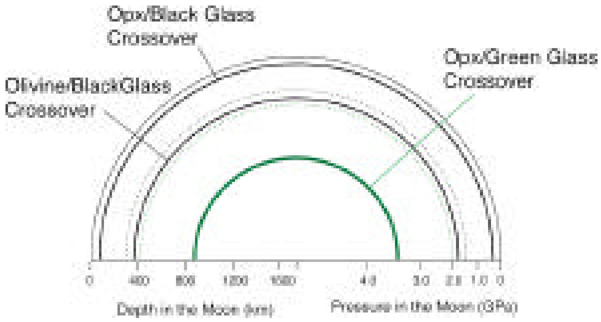


Apollo 15 Green Glass Density Crossovers. Density measurements of molten Apollo 15 "green glass" have been performed in the pressure range 0.5-3.5 GPa using the floating and sinking spheres technique in piston-cylinder and multi-anvil devices. A density crossover with equilibrium orthopyroxene is predicted for green glass at 3.5 GPa, or approximately 880 km depth in the lunar interior. Equilibrium olivine should be neutrally buoyant at pressures greater (5-6 GPa) than the lunar core value of ~4.7 GPa. At the olivine-orthopyroxene cotectic (~2.0 GPa), molten green glass is less dense than both crystalline phases. Thus, the results are consistent with models that propose generation and buoyant rise of this magma from the depth of the olivine-orthopyroxene cotectic in the lunar interior.





Apollo 14 Black Glass Density Crossovers. Circone and Agee (1996) showed that high-Ti lunar picrite (Apollo 14 "black glass") is denser than coexisting liquidus phases orthopyroxene and olivine at pressures of 0.4 and 1.8 GPa respectively, which corresponds to depths of 70 and 375 km in the lunar mantle. These data argue against high-Ti magmas being generated and transported from regions below the level of crystal-liquid neutral buoyancy and supports the original prediction of density crossovers by Delano (1990). In fact, it is possible that molten black glass is denser than the solid residue at the orthopyroxene-olivine cotectic pressure (Wagner and Grove, 1996) of 1.5 GPa (300 km depth).



Molten Green Glass Compressibility. The information gained from the sink-float experiments can also be used to elucidate the effect of composition on silicate melt compressibility. Two known densities, at 1 bar and 3 GPa, permit a family of solutions for Birch-Murnaghan K and K' to be calculated. Adopting the Lange and Carmichael (1987) bulk modulus of 18.0 GPa a K' value of 5.3 is calculated for this melt. For comparison, we note that the Lange and Carmichael bulk modulus for molten black glass at 1645°C is 16.6 GPa. What compositional effects can account for the differences in the melt compressibilities? Green glass and black glass differ significantly in SiO_2, TiO_2, FeO, and MgO concentration but when summed, the SiO_2 + TiO_2 and FeO + MgO of the two melts are nearly equal. At 1645°C Lange and Carmichael give the following values for the liquid oxides: K= 14.4 for SiO_2, K=10.2 GPa for TiO_2, and 19.0 GPa for FeO, and 19.2 GPa MgO. Hence, large variations in SiO_2/TiO_2 will have a marked effect on compressibility while the FeO/MgO does not.

Molten Black Glass Compressibility. Density measurements of molten black glass were performed by the sink/float method from 1.5 to 11.5 GPa. Birch-Murnaghan compression curves for each sink/float measurement calculated with K'=4 to 12. The figure below shows these data cast in terms of bulk modulus versus temperature. Each assumed value of K' (4 through 12) produces a dK/dT path through the data. All of the dK/dT paths are distinctly non-linear. In other words, dK/dT is a function of temperature. Another interesting feature of this figure is that for K' between 4 and 6, dK/dT changes sign from negative to positive at temperatures >1800°C

Compositional Effect on K'? We assume that black glass dK/dT decreases (but remains negative) with temperature. It is also possible that some of the apparent decrease in dK/dT along the black glass liquidus, may be due to an increase in K' with pressure. The data are also consistent with K' being larger than 6, with values of K'=12 or greater being allowable. It is intriguing to note that this may be in accord with the hypothesis of Stolper and Ahrens (1987) and Rigden et al. (1989). In their analysis, melts with high concentrations of tetrahedrally coordinated species such as Si and Al, tend to have values of K' that are relatively small. K' is small in these cases because the tetrahedrally coordinated Si and Al change to octahedral coordination gradually, over a large pressure interval. Thus the melt Si-O-Si structure collapses incrementally like an accordion and melt remains "compressible" up to very high pressures. In contrast, melts with lower levels of tetrahedrally coordinated species, with less of the Si-O-Si accordion-like structure, tend to become rapidly incompressible with pressure. The Stolper-Ahrens-Rigden (SAR) hypothesis used molten forsterite and fayalite as examples of low Si compositions with large values of K'=10-12. Agee (1992) measured the isothermal density of molten fayalite up to 5.5 GPa and found that the best fit is K'=10.1, in excellent agreement with the SAR hypothesis. Molten black glass may also fall within the category of high K' melts. Black glass is a lunar basalt, but unlike terrestrial basalts the SiO_2 content is very low (~35 wt%) and the TiO_2 content is very high. Lange and Carmichael (1987) and Webb and Dingwell (1994) have argued that Ti^{+4} is octahedrally coordinated in melts such as black glass. Hence a significant fraction of the melt is already octahedrally coordinated at 1-bar of pressure. Only a modest fraction of the melt structure is accordion-like and not surprisingly, our results show that K' is likely to be comparatively large in this composition. It would be desirable to test this idea further by examining melts with variable TiO_2 and SiO_2 (Al_2O_3) contents. Currently we are undertaking this task by measuring the density of low-Ti lunar "green glass" at higher pressures and intermediate-Ti "orange glass", the results of which will be contained in a forthcoming report.